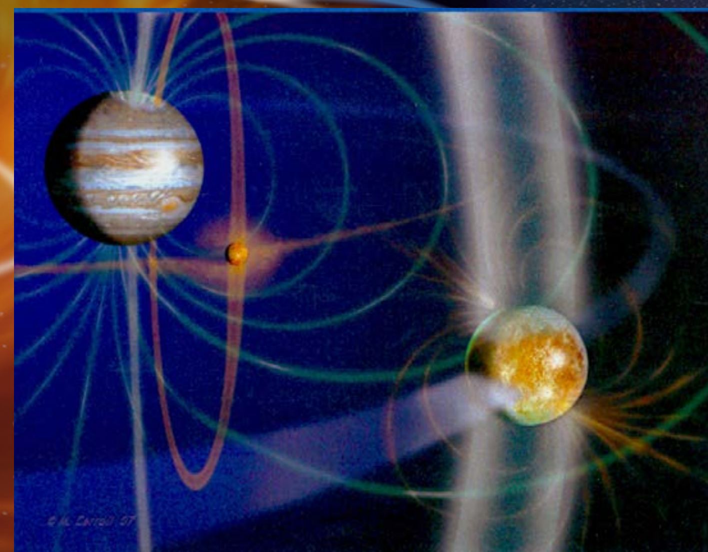
MeV Electron Bombardment of Europa Surface Analogs



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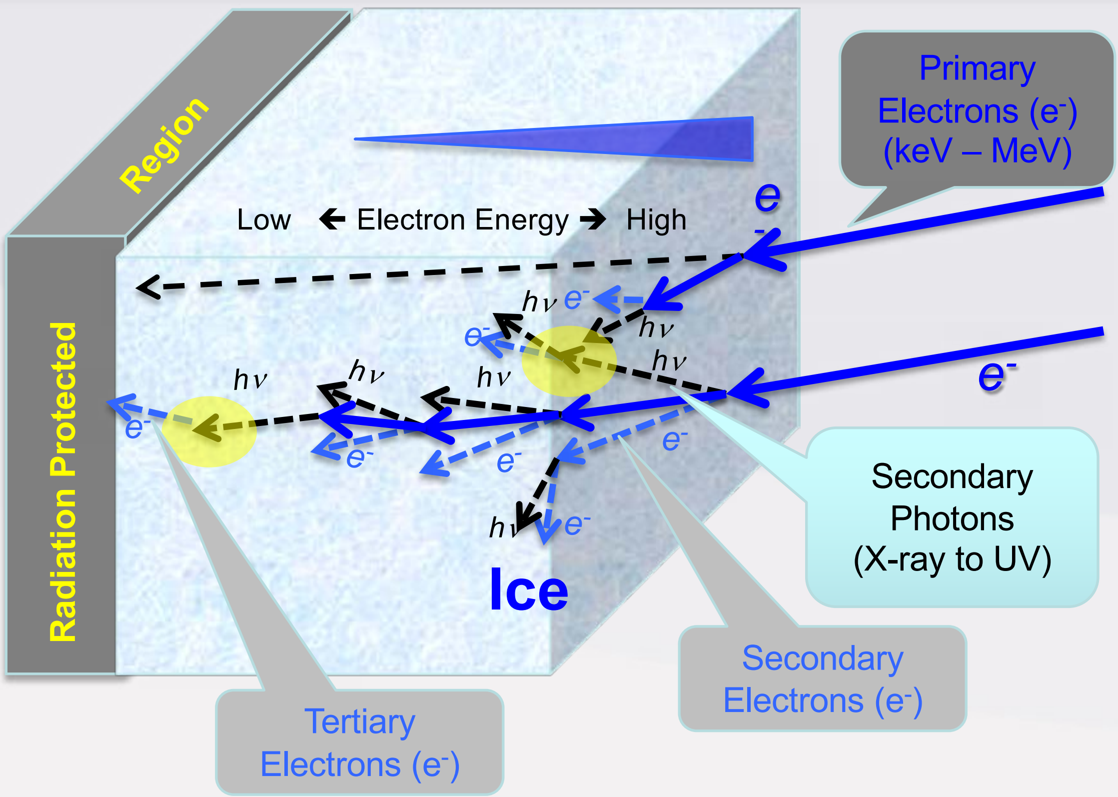
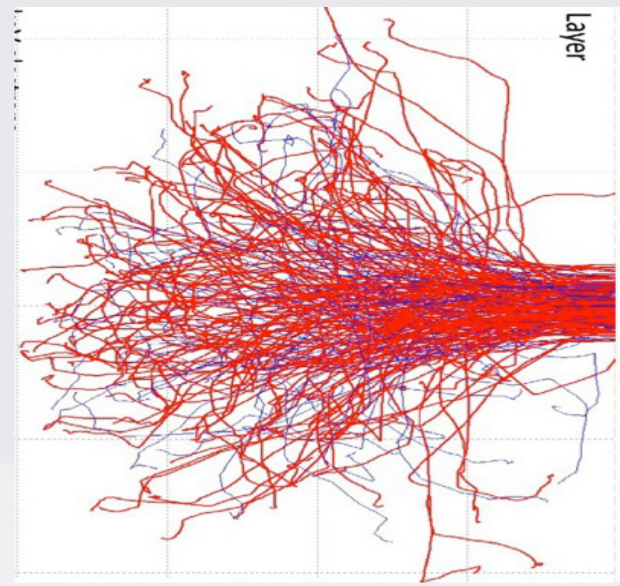
DPS-50, Knoxville, TN; Oct 25, 2018

Statistical Nature of Particles
Electrons, Photons, and Ions

Electron Impact on Matter: Primary and Secondary Radiation





ElectronTrajectory Simulation Through Materials

The Approach

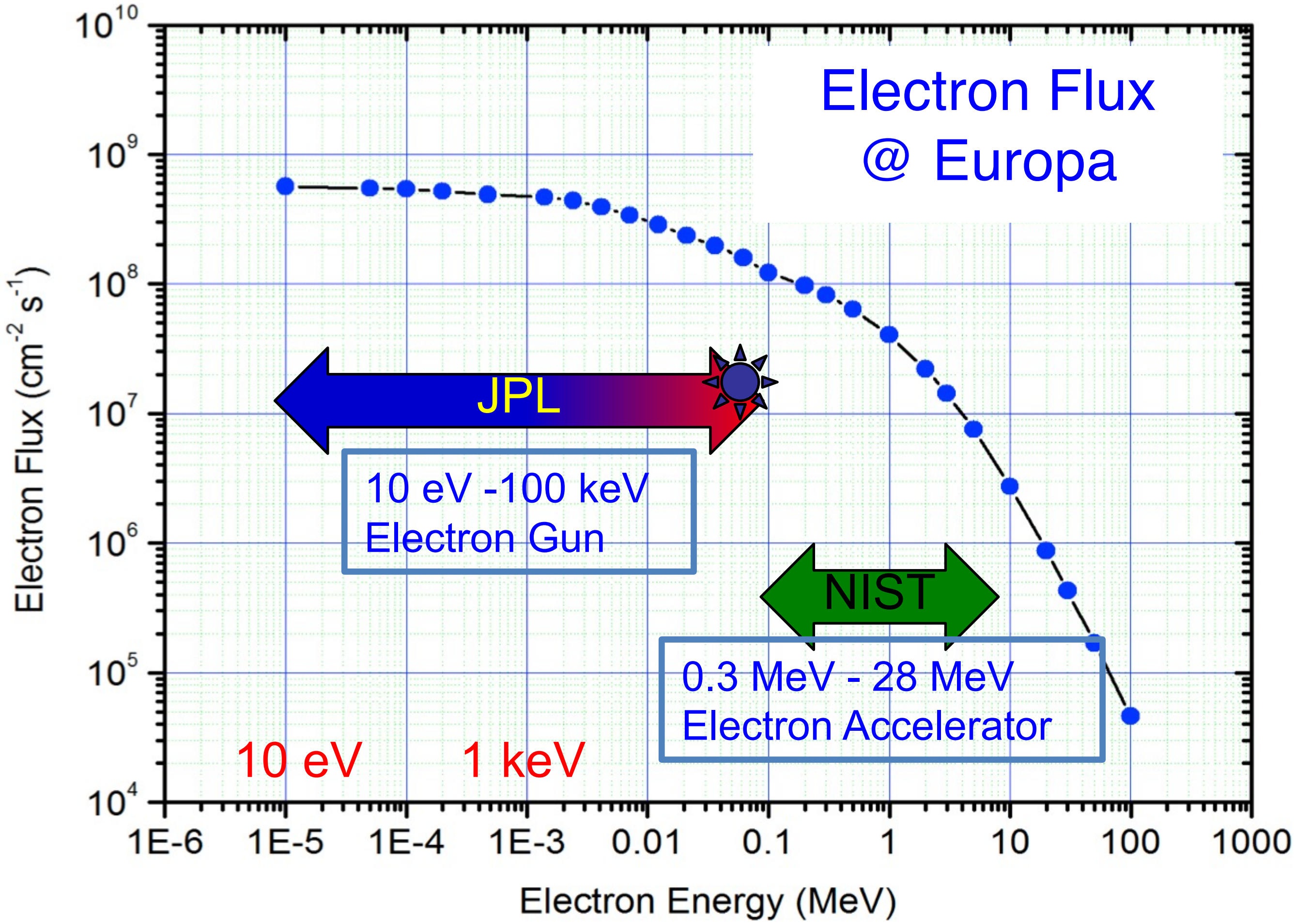
Laboratory Experimental Data

Complemented/Constrained

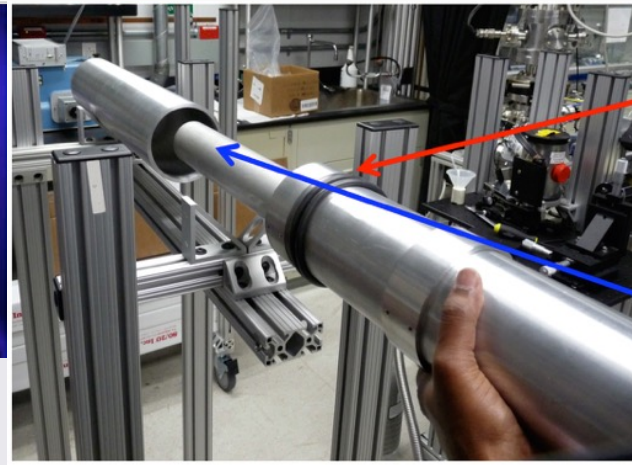
Modeling Work of the Observed Data

Present Capabilities of the ISL @ JPL

Europa's Trailing-Leading Cutoff
20 MeV?
25 MeV?



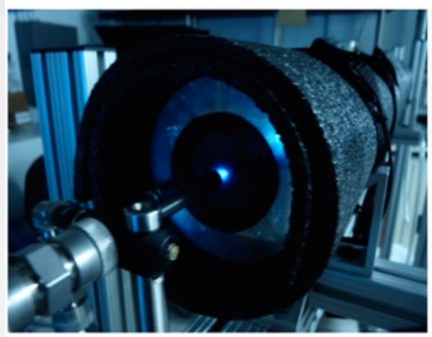
Ice Chamber for Europa’s High-Energy Electron And Radiation-Environment Testing



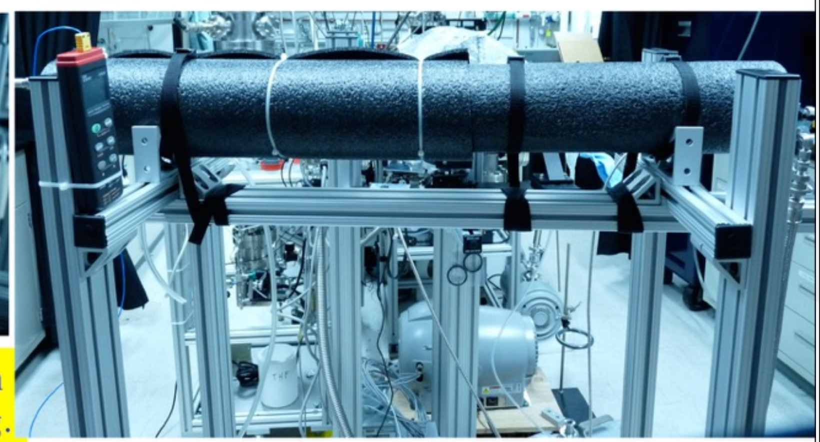
Outer Telescope with vacuum seal O-rings.

Inner 2.5-inch diameter tube for water ice frozen in the tube or loaded as crushed powder.

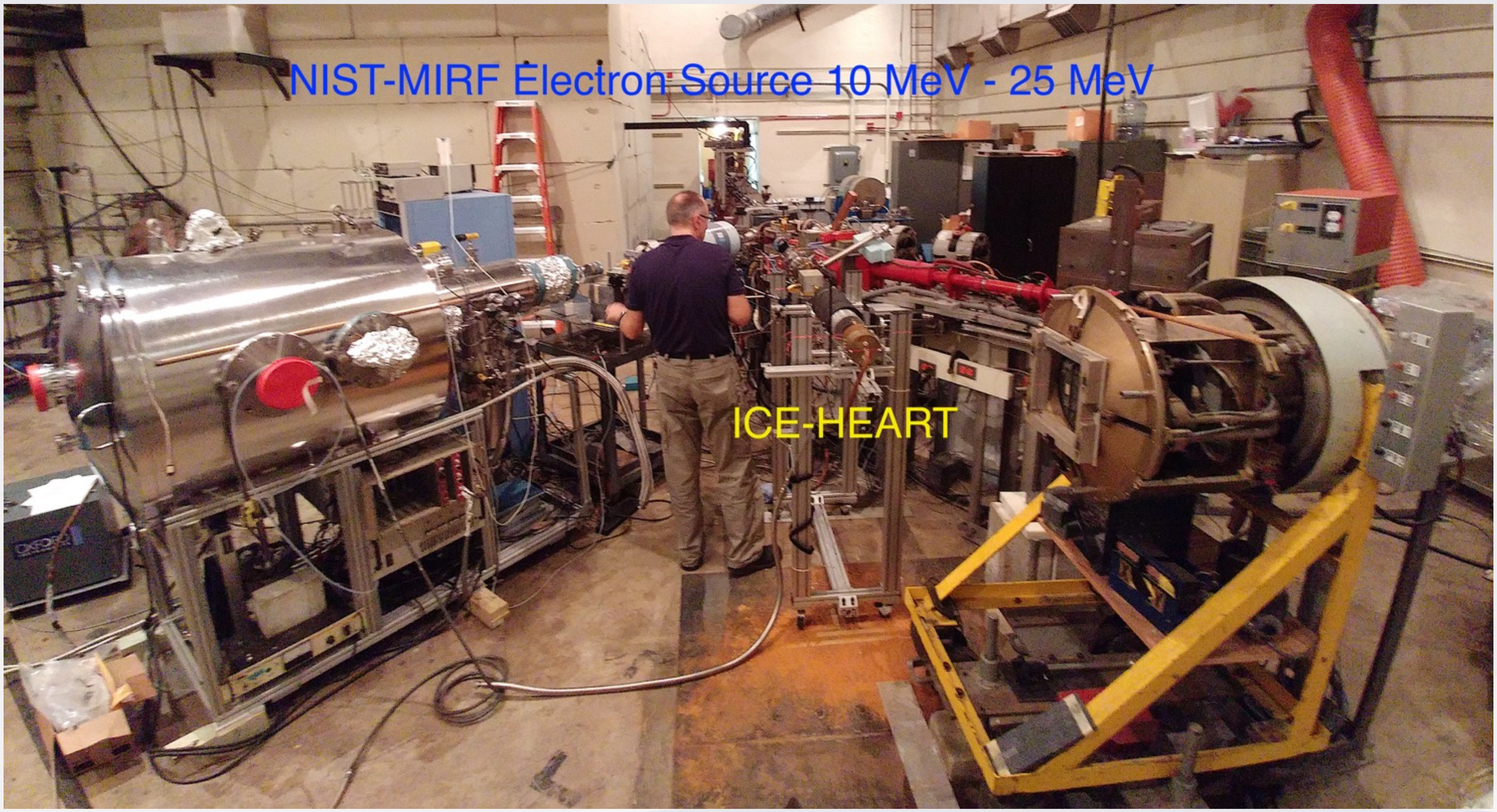
(ICE-HEART)
~100 K and >
~ 1cm – 100 cm



Insulated for 100 K operation
Using liquid nitrogen cooling.



NIST Electron Sources Cover 300 keV to 28 MeV

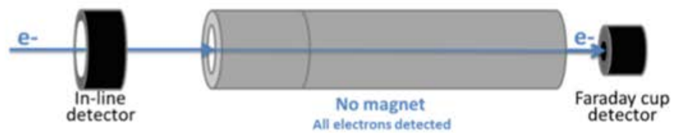


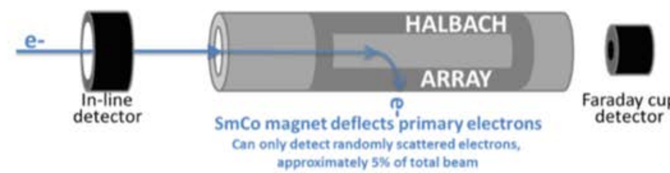
ICE-HEART Crew in Action @ NIST MIRF

Ice Sample Handling in (subsequent to) High-Radiation Environment

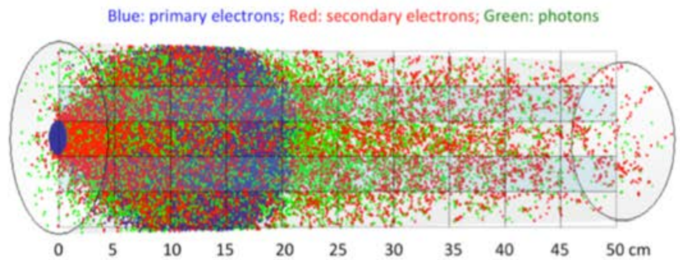
How to Quantify Bremsstrahlung (X-rays)?

By Removing Secondary Electrons



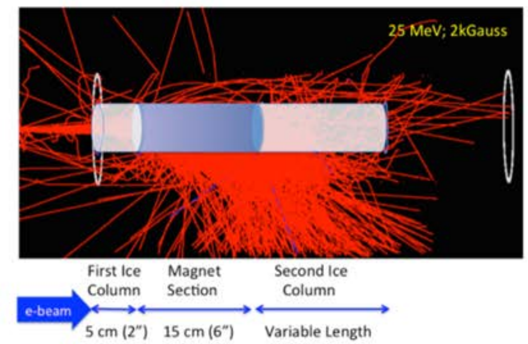


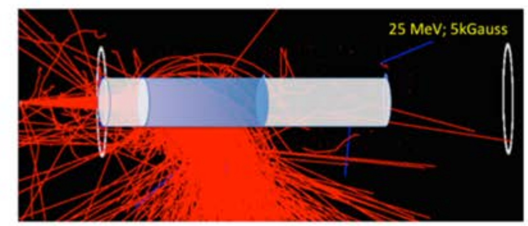
5kG Halbach Cylindrical Magnet @ 80 K Deflecting Primary and Secondary Electrons Enables Quantification of X-ray Yields and Penetration Depths



Above: typical secondary particle generation in the ICE-HEART when high energy electrons impinge upon ice with no magnet.

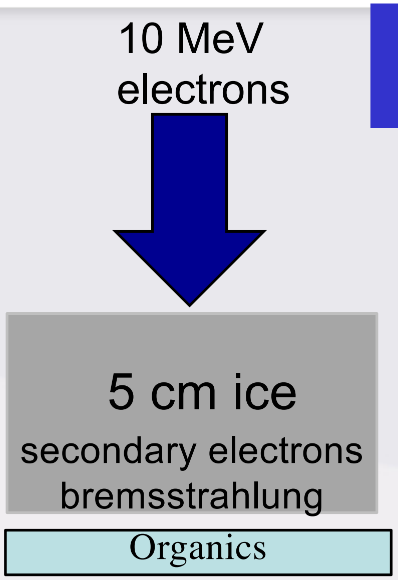
Right: Inserting a strong SmCo magnet (5 kGauss) into the chamber causes electrons to be deflected to the side, so that they no longer impinge upon the detector.



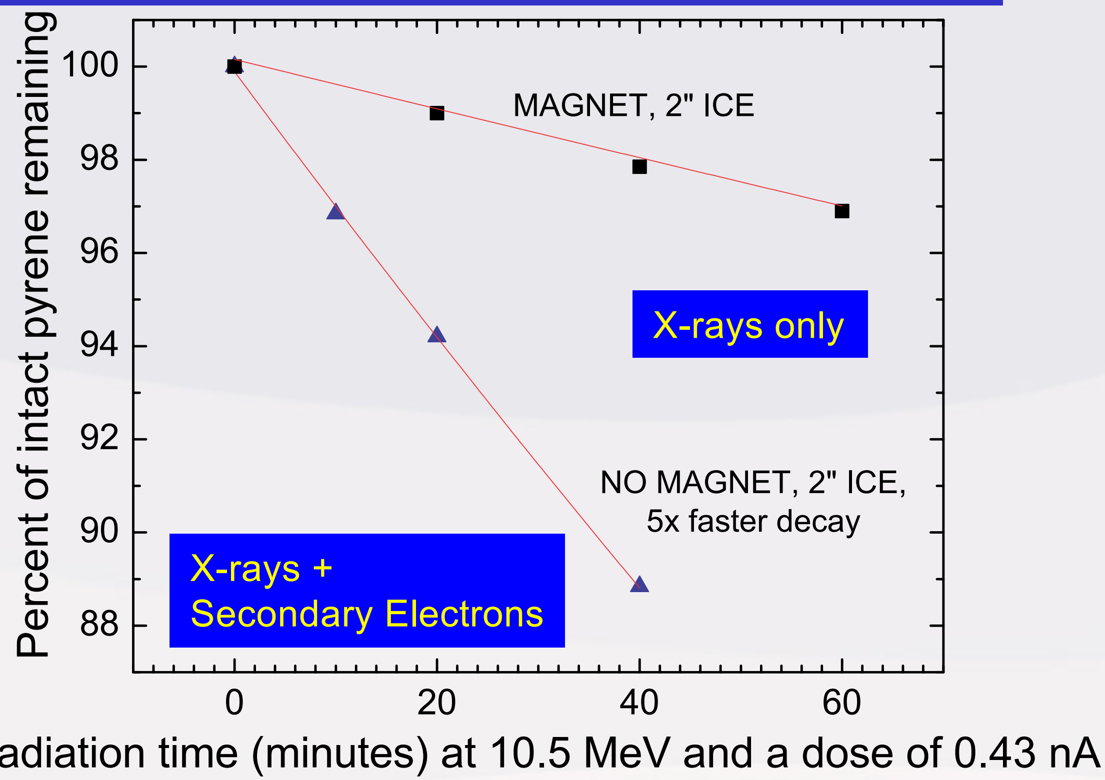


Stating the Observational Facts

Secondary Electrons vs. X-rays



First JPL-NIST MIRF Data for 10 MeV Primary Electrons bombarding 5 cm thick ice targets at 100 K



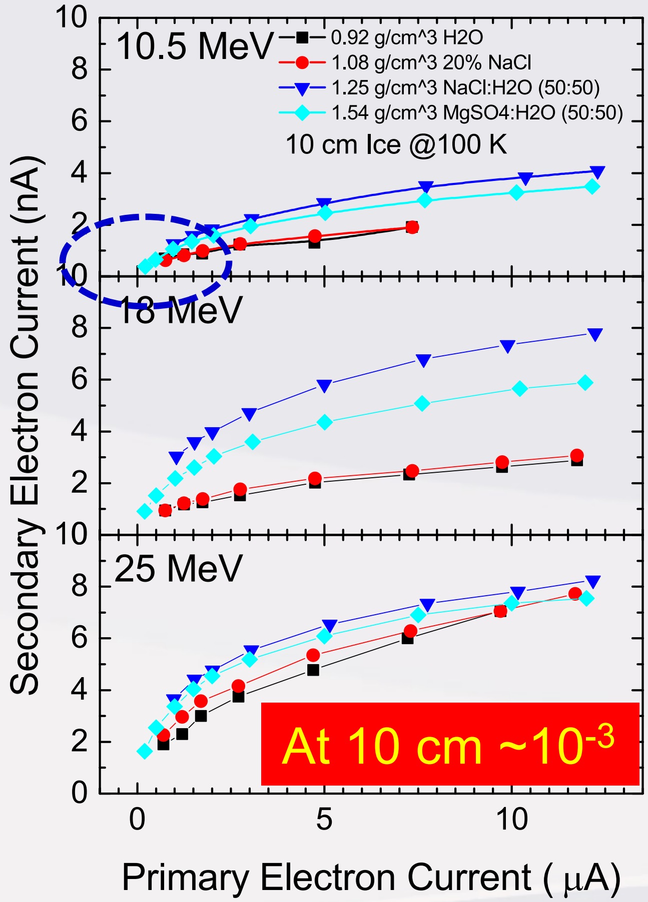
Damage by Electrons 80%
X-rays 20%

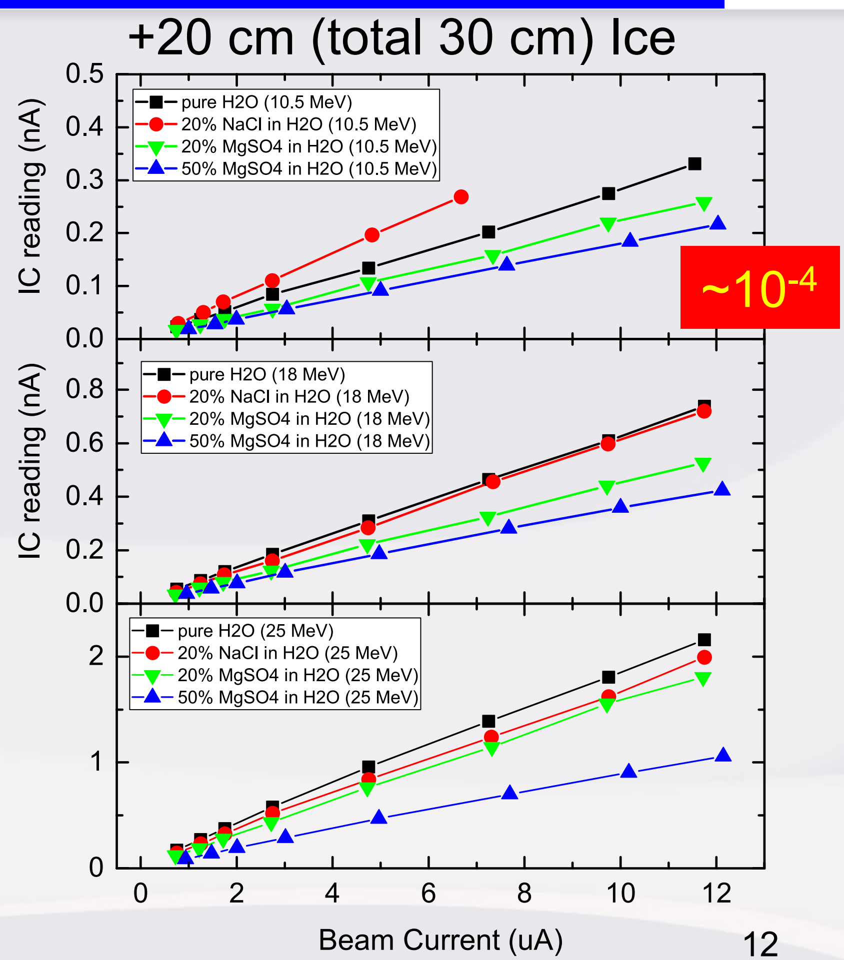
Europa Ice Analogs (10 cm) with NaCl & $MgSO_4$

Electrons @ 10 cm

Bremsstrahlung @ 30 cm

Electrons:
0.1 % @ 10 cm
X-rays:
<0.01% @ 30 cm

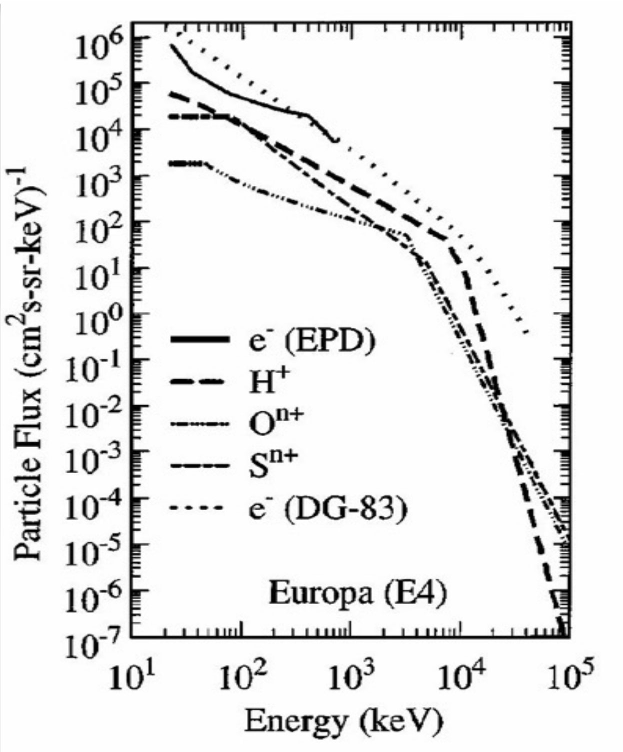




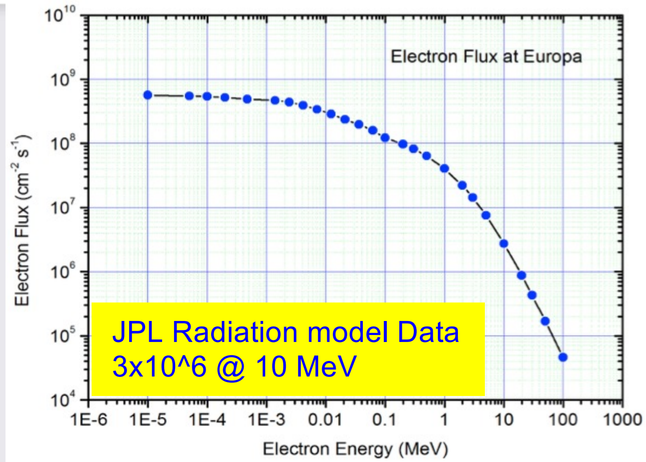
Reconciliation between Lab Data and Modeling

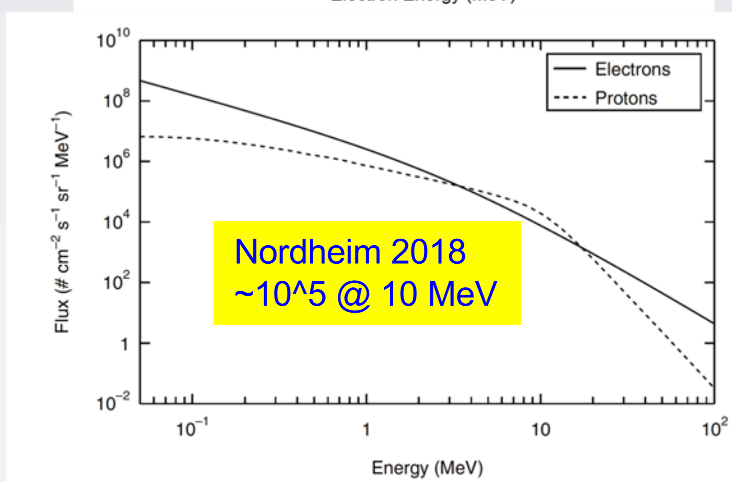
Accuracy of the MeV Electron Fluxes at Europa?

6 – 50 times Difference



Cooper et al. 2001
~10^6 @ 10 MeV





10 MeV/Total Flux
3E6/5E8 = **6E-3**

20 MeV/Total Flux
1E6/5E8 = **2E-3**

25 MeV/Total Flux
7E5/5E8 = **1.4E-3**

10 MeV/Total Flux
1E5/5E8 = **1E-3**

20 MeV/Total Flux
2E4/5E8 = **4E-5**

25 MeV/Total Flux
1.5E4/5E8 = **3E-5**

Back of the Envelop with 10 cm Ice

1 Yr on the Surface = 0.2 Myr @ 10 cm @ 10 MeV

Electrons ONLY (Bremsstrahlung NOT Included)

Electron Flux After/Incident (nA/μA):
10^{-3} (10 MeV); 2×10^{-3} (18 MeV); 4×10^{-3} (25 MeV)

Flux/Total Flux at the Surface:
6×10^{-3} (10 MeV); 2×10^{-3} (18 MeV); 1×10^{-3} (25 MeV)

Electron Flux after 10 cm Ice on Europa:
6×10^{-6} (10 MeV); 4×10^{-6} (18 MeV); 4×10^{-6} (25 MeV)

It will take ~2×10^{5} Units of time for the same dose at 10 cm depth

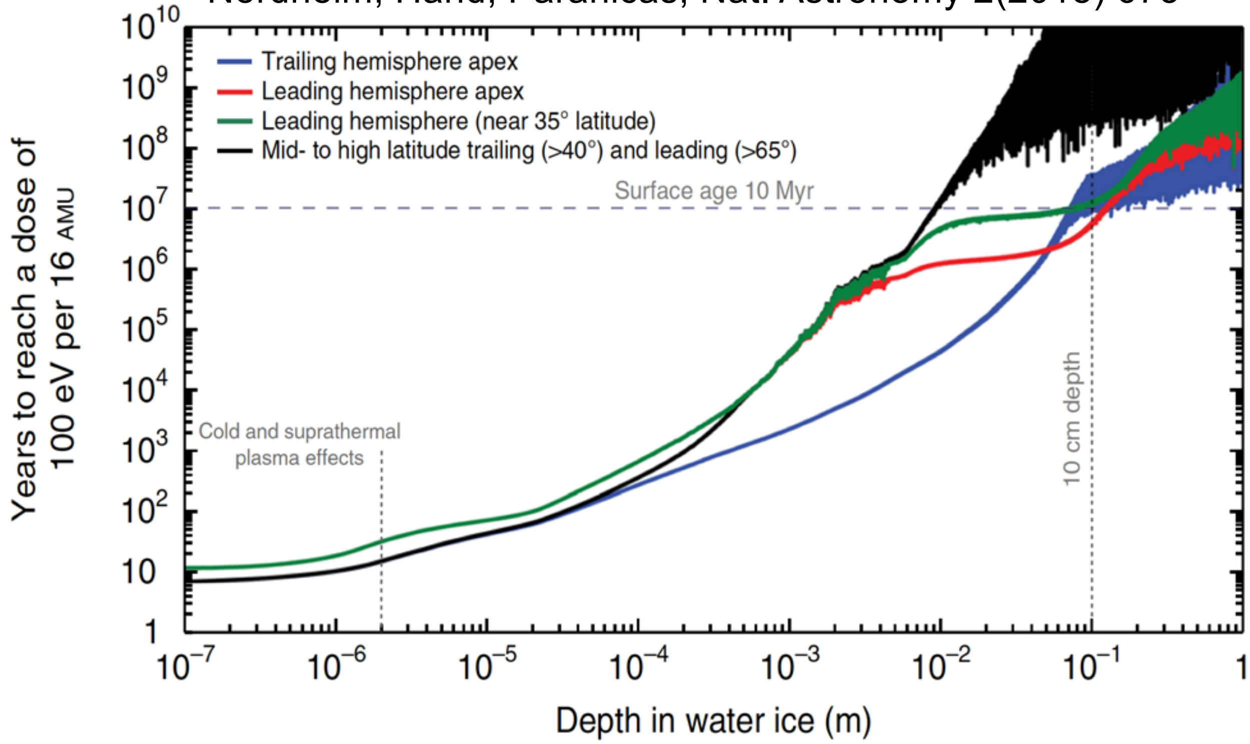
Electrons @ Europa: Conclusions

Disagreements persist – need to be further investigated

Nordheim et al., 2018
Surface Equivalent Dose
Of all the influx electrons:
≤10 cm in 10 Myr

Gudipati et al., unpublished
Surface-equivalent Dose
10 MeV = 0.2Myr @ ~10 cm
25 MeV = 0.2Myr @ ~15 cm

Nordheim, Hand, Paranicas; Nat. Astronomy 2(2018) 673



Bremsstrahlung at 30 cm Depth

Bresmsstrahlung Flux After/Incident (nA/μA):
10^{-5} (10 MeV); $2x10^{-5}$ (18 MeV); $1x10^{-4}$ (25 MeV)

Flux/Total Flux at the Surface:
$6x10^{-3}$ (10 MeV); $2x10^{-3}$ (18 MeV); $1x10^{-3}$ (25 MeV)

Electron Flux after 10 cm Ice on Europa:
$6x10^{-8}$ (10 MeV); $4x10^{-8}$ (18 MeV); $1x10^{-7}$ (25 MeV)

It will take ~10^{7} Units of time for the same dose at 30 cm depth

If Damage Efficiency of Bremsstrahlung is 10%
Compared to Electrons (our preliminary results ~20%)
~100 Myr for surface equivalent does at 30 cm depth.

Conclusions

- There is disagreement between modeling predictions and Laboratory Data (~1-2 orders of magnitude)
- Europa's surface radiation processing depths are dictated by the "age of the surface layer" – 1 yr – 100 Myr?
- Younger landforms (<100 kyr) are likely to be less processed at ~10 cm depths throughout Europa.
- Laboratory data and modeling studies need to be continued and converged.

Thank You for Your Time!

Funding:
JPL R&TD Funds (2014-2016)

After 5 Years of Proposing, Finally We are Selected to Continue this Work!
Thanks to NASA SSW Funding (2018 -)

Keep Tuned for Publications and Further Work!

The END